PATENT APPLICATION
DOCKET NO. L7089-0001

WHAT IS CLAIMED IS: computer implemented

Nonstatutory.

Abstract Idea

not techo embodied

1. A computer implemented method of optimizing tolerances for a design and assembly of a plurality of components, said method comprising the steps of:

defining an assembly requirement;

defining datum features;

assigning component dimensions;

creating a dimensional loop diagram for each component;

determining an appropriate analysis/allocation method for determining tolerances of the plurality of components;

applying variation controls to features of the plurality of components; and

assigning tolerances to features of the plurality of components.

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2. The method of optimizing tolerances for a design of claim 1 wherein the step of applying variation controls for the plurality of components includes defining feature material condition modifiers.

3. The method of optimizing tolerances for a design of claim 2 wherein said step of defining feature material condition modifiers includes assigning a geometric control at a maximum material condition when a feature of one of the components requires a boundary of air.

4. The method of optimizing tolerances for a design of claim 2 wherein said step of defining feature material modifiers includes assigning a geometric control at a least material condition when a feature of one of the components requires a boundary of material.

5. The method of optimizing tolerances for a design of claim 2 wherein said step of defining material condition modifiers includes calculating effects of a least material condition or a maximum material condition on a controlled feature of one of the components.

6. The method of optimizing tolerances for a design of claim 5 wherein said step of calculating effects of a least material condition or maximum material condition modifier of the controlled feature includes:

determining if the controlled feature is external or internal and at maximum materia condition or least material condition;

upon determining that the controlled feature is external and at maximum material condition or internal and at least material condition, decreasing a mean of the controlled feature by:

$[(PlusTol_i + MinusTol_i)/2)]$

where

$PlusTol_i$= a positive tolerance value of the feature associated with the material condition modifier; and

$MinusTol_i$= a negative tolerance value of the feature associated with the material condition modifier.

7. The method of optimizing tolerances for a design of claim 6 where the controlled feature's tolerance is adjusted by:

$+/-[(PlusTol_i + MinusTol_i)/2]$.

8. The method of optimizing tolerances for a design of claim 5 wherein said step of calculating the effects of a least material condition or maximum material condition modifier of the controlled feature includes:

determining if the controlled feature is external or internal and at maximum material condition or least material condition;

upon determining that the controlled feature is external and at least material condition or internal and at maximum material condition, decreasing a mean of the control feature by:

$[(PlusTol_i+MinusTol_i)/2]$

where

$PlusTol_i$= a positive tolerance value of the feature associated with the material condition modifier; and

$MinusTol_i$= a negative tolerance value of the feature associated with the material condition modifier.

9. The method of optimizing tolerances for a design of claim 8 where the controlled feature's tolerance is adjusted by:

$+/-[(PlusTol_i+MinusTol_i)/2]$.

10. The method of optimizing tolerances for a design of claim 5 wherein said step of calculating effects of a least material condition or maximum material condition modifier includes shifting the controlled feature by:

$|a_i|[0 +/- (PlusTol_i + MinusTol_i)/2]$

where

a_i=sensitivity of the i^{th} axis/center plane/center point component of the controlled feature;

$PlusTol_i$= a positive tolerance value of the feature associated with the material condition modifier; and

$MinusTol_i$= a negative tolerance value of the feature associated with the material condition modifier.

11. The method of optimizing tolerances for a design of claim 2 wherein said step of defining material modifiers includes the step of calculating effects of a least material condition or a maximum material condition modifier of a datum feature of one of the components.

12. The method of optimizing tolerances for a design of claim 11 wherein said step of calculating the effects of a least material condition or a maximum material condition modifier includes:

determining if the plurality of components are referenced simultaneously to the datum feature; and

upon determining that the plurality of components are referenced simultaneously to the datum feature by not shifting the datum.

13. The method of optimizing tolerances for a design of claim 11 wherein said step of calculating effects of a least material condition or a maximum material modifier condition includes:

determining if the plurality of components are referenced separately or simultaneously to the datum feature;

upon determining that the plurality of components are referenced separately, determining if the datum is primary, secondary, or tertiary;

upon determining that the datum is primary, determining if the datum is controlled with axis straightness, center plane straightness, or center plane flatness; and

upon determining that the datum is controlled with axis straightness, center plane straightness, or center plane flatness, shifting the datum by:

$|a_i|[0+/-(PlusTol_i + MinusTol_i + GeoTol_i)/2]$

where

a_i=sensitivity of the i^{th} axis/center plane/center point component of the datum feature;

$PlusTol_i$= a positive tolerance value of the datum feature;

$MinusTol_i$= a negative tolerance value of the datum feature; and

$GeoTol_i$= a tolerance in a feature control frame of the datum feature.

14. The method of optimizing tolerances for a design of claim 11 wherein said step of calculating effects of a least material condition or a maximum material modifier condition includes:

determining if the plurality of components are referenced separately to the datum feature;

upon determining that the plurality of components are referenced separately, determining if the datum is primary, secondary, or tertiary;

upon determining that the datum is primary, determining if the datum is controlled with axis straightness, center plane straightness, or center plane flatness; and

upon determining that the datum is not controlled with axis straightness, center plane straightness, or center plane flatness, shifting the datum by:

$|a_i|[0 +/- (PlusTol_i + MinusTol_i)/2]$

where

a_i=sensitivity of the i^{th} axis/center plane/center point component of the datum feature;

$PlusTol_i$= a positive tolerance value of the datum feature; and

$MinusTol_i$= a negative tolerance value of the datum feature.

15. The method of optimizing tolerances for a design of claim 11 wherein said step of calculating effects of a least material condition or a maximum material modifier condition includes:

determining if the plurality of components are referenced separately to the datum feature;

upon determining that the plurality of components are referenced separately, determining if the datum is primary, secondary, or tertiary;

upon determining that the datum is secondary or tertiary, shifting the datum by:

$|a_i|[0+/-(\mathrm{PlusTol}_i + \mathrm{MinusTol}_i + \mathrm{GeoTol}_i)/2]$

where

a_i=sensitivity of the i^{th} axis/center plane/center point component of the datum feature;

$\mathrm{PlusTol}_i$= a positive tolerance value of the datum feature;

$\mathrm{MinusTol}_i$= a negative tolerance value of the datum feature; and

GeoTol_i= a tolerance in a feature control frame of the datum feature.

16. The method of optimizing tolerances for a design of claim 11 wherein said step of calculating effects of a least material condition or a maximum material modifier condition includes:

determining if the datum is primary, secondary or tertiary;

upon determining that the datum is primary, determining if the datum is controlled with axis straightness, center plane straightness, or center plane flatness; and

upon determining that the datum is controlled with axis straightness, center plane straightness, or center plane flatness, shifting the datum by:

$|a_i|(0 +/- GeoTol_i /2)$

where

a_i=sensitivity of the i^{th} component of the datum feature associated with the material condition modifier; and

$GeoTol_i$= a tolerance in a feature control frame of the datum feature.

17. The method of optimizing tolerances for a design of claim 16 wherein said step of calculating a least material condition or a maximum material condition includes:

determining if the datum is primary, secondary or tertiary;

upon determining that the datum is primary, determining if the datum is controlled with axis straightness, center plane straightness, or center plane flatness; and

upon determining that the datum is not controlled with axis straightness, center plane straightness, or center plane flatness, determining if the datum feature is external or internal and at maximum material condition or at least material condition;

upon determining that the datum feature is external and at maximum material condition or internal and at least material condition, decreasing the feature's mean by:

$(PlusTol_i+MinusTol_i)/2$; and

adjusting a tolerance of the datum feature by:

$+/-[(PlusTol_i+MinusTol_i)/2]$

where

$PlusTol_i$= a positive tolerance value of the datum feature; and

$MinusTol_i$= a negative tolerance value of the datum feature.

18. The method of optimizing tolerances for a design of claim 16 wherein said step of calculating a least material condition or a maximum material condition includes:

determining if the datum is primary, secondary or tertiary;

upon determining that the datum is primary, determining if the datum is controlled with axis straightness, center plane straightness, or center plane flatness; and

upon determining that the datum is not controlled with axis straightness, center plane straightness, or center plane flatness, determining if the datum feature is external or internal and at maximum material condition or at least material condition; and

upon determining that the datum feature is external and at least material condition or internal and at maximum material condition, increasing the feature's mean by:

$$[(PlusTol_i+MinusTol_i)/2];$$ and

adjusting a tolerance of the feature by:

$$+/- [(PlusTol_i+MinusTol_i)/2]$$

where

$PlusTol_i$= a positive tolerance value of the datum feature; and

$MinusTol_i$= a negative tolerance value of the datum feature.

19. The method of optimizing tolerances for a design of claim 11 wherein said step of calculating a least material condition or a maximum material condition includes:

determining if the datum is primary, secondary or tertiary;

upon determining that the datum is primary, determining if the datum is controlled with axis straightness, center plane straightness, or center plane flatness; and

upon determining that the datum is controlled with axis straightness, center plane straightness, or center plane flatness, shifting the datum by:

$|a_i|(0 +/- GeoTol_i)/2$

where

a_i=sensitivity of the i^{th} component of the datum associated with the material condition modifier; and

$GeoTol_i$= a tolerance in a feature control frame of the datum feature.

20. The method of optimizing tolerances for a design of claim 1 wherein the step of determining an appropriate analysis/allocation method for determining tolerances of the plurality of components includes the following steps:

determining if process data is available for assembling the plurality of components;

upon determining that process data is not available, determining if the plurality of components analyzed number four or more; and

upon determining that the plurality of components are not four or more, selecting a worst case analysis.

21. The method of optimizing tolerances for a design of claim 20 wherein the step of determining an appropriate analysis/allocation method for determining tolerances of the plurality of components includes the following steps:

upon determining that the plurality of components number four or more, determining if a cost of an assembly defect is high in comparison to a cost of a component defect; and

upon determining that the cost of an assembly defect is high, selecting a worst case analysis.

22. The method of optimizing tolerances for a design of claim 21 wherein the step of determining an appropriate analysis/allocation method for determining tolerances of the plurality of components includes the following steps:

upon determining that the cost of an assembly defect is low, determining if manufacturing processes of the plurality of components are understood; and

upon determining that the manufacturing processes are understood, selecting a root sum of the squares analysis.

23. The method of optimizing tolerances for a design of claim 22 further comprising the step of, upon determining that the manufacturing processes are not understood, selecting a modified root sum of the squares analysis.

24. The method of optimizing tolerances for a design of claim 1 wherein the step of determining an appropriate analysis/allocation method for determining tolerances of the plurality of components includes the following steps:

determining if process data is available for assembling the plurality of components;

upon determining that process data is available, the step of determining if a cost of an assembly defect is high in comparison to a cost of a component defect; and

upon determining that the cost of an assembly defect is high, selecting a worst case allocation.

25. The method of optimizing tolerances for a design of claim 24 wherein the step of determining an appropriate analysis/allocation method for determining tolerances of the plurality of components includes:

upon determining that the cost of an assembly defect is low, determining if all data can be treated as short-term with a mean shift of 1.5 standard deviations; and

upon determining that all data can be treated as short-term with a mean shift of 1.5 standard deviations, selecting a static root sum of the squares allocation.

26. The method of optimizing tolerances for a design of claim 25 wherein the step of determining an appropriate analysis/allocation method for determining tolerances of the plurality of components includes:

upon determining that all data cannot be treated as short-term with a mean shift of 1.5 standard deviations, determining if cost of the assembly or parts is a cost driver;

upon determining that parts are the cost driver, selecting statistical allocation.

27. The method of optimizing tolerances for a design of claim 26 wherein the step of determining an appropriate analysis/allocation method for determining tolerances of the plurality of components includes upon determining that assembly costs are the cost driver, selecting root sum of squares allocation.

28. The method of optimizing tolerances for a design of claim 1 further comprising the step, after the step of determining an appropriate analysis/allocation method for determining tolerances of the plurality of components, the steps of:

selecting a worst case analysis of the requirement;

calculating a requirement variation, wherein the variation is determined by:

$$t_{wc} = \sum_{i=1}^{n} |a_i t_i| + \sum_{m=1}^{r} |a_m t_m|$$

where

a_i=sensitivity of the i^{th} component;

a_m= sensitivity of the m^{th} material condition modifier;

m= number of material modifier components;

n=number of independent components;

r=number of incremental tolerances due to material condition modifiers;

t_i= equal bilateral tolerance of the i^{th} component;

t_m= equal bilateral tolerance of the m^{th} material condition modifier; and

t_{wc}=maximum expected variation of a requirement using the worst case analysis.

29. The method of optimizing tolerances for a design of claim 1 further comprising the step, after the step of determining an appropriate analysis/allocation method for determining tolerances of the plurality of components, the steps of:

selecting a root sum of the squares analysis of the process;

calculating a requirement variation, wherein the variation is determined by:

$$t_{rss} = \left[\sum_{i=1}^{n} (a_i t_i)^2 + \sum_{m=1}^{r} (a_m t_m)^2 \right]^{1/2}$$

where

a_i=sensitivity of the i^{th} component;

a_m= sensitivity of the m^{th} material condition modifier;

m= number of material modifier components;

r=number of incremental tolerances due to material condition modifiers;

n=number of independent components;

t_i= equal bilateral tolerance of the i^{th} component;

t_m= equal bilateral tolerance of the m^{th} material condition modifier; and

t_{rss}=maximum expected variation of the requirement using the root sum of the squares analysis.

30. The method of optimizing tolerances for a design of claim 1 further comprising the step, after the step of determining an appropriate analysis/allocation method for determining tolerances of the plurality of components, the steps of:

selecting a modified root sum of the squares analysis of the process;

calculating a requirement variation, wherein the variation is determined by:

$$t_{mrss} = C_f \left[\sum_{i=1}^{n} (a_i t_i)^2 + \sum_{m=1}^{r} (a_m t_m)^2 \right]^{1/2}$$

where

a_i=sensitivity of the i^{th} component;

a_m= sensitivity of the m^{th} material condition modifier;

C_f =correction factor;

m= number of material modifier components;

n=number of independent components;

r=number of incremental tolerances due to material condition modifiers;

t_i= equal bilateral tolerance of the i^{th} component;

t_m= equal bilateral tolerance of the m^{th} material condition modifier; and

t_{mrss}=maximum expected variation of the requirement using the modified root sum of the squares analysis.

31. The method of optimizing tolerances for a design of claim 1 wherein:

the step of assigning tolerances to components includes:

determining defects per opportunity goal for each requirement variable;

assigning the process with a largest standard deviation for each variable component;

converting short-term data to long-term data;

calculating an assembly number of defects per opportunity from a standard normal deviate associated with an upper and lower specification limit;

assigning tolerances to a plurality of variable components; and

calculating defects per opportunity for each variable component.

32. The method of optimizing tolerances for a design of claim 31 wherein:

the step of determining an appropriate analysis/allocation method for determining tolerances of the plurality of components includes selecting a worst case, statistical or root sum of the squares allocation; and

the step of converting short-term data to long-term data is calculated by:

$$\sigma_{i,LT} = \left(\frac{1}{1-k_i}\right) w_i \sigma_{i,ST}$$

where

$\sigma_{i,LT}$= long-term standard deviation for the i^{th} component;

k_i= factor that considers mean shift of the i^{th} component;

$\sigma_{i,ST}$= short-term standard deviation for the i^{th} component; and

w_i= weight factor for the i^{th} component.

33. The method of optimizing tolerances for a design of claim 1 wherein the step of determining an appropriate analysis/allocation method for determining tolerances of the plurality of components includes selecting a statistical or root sum of the squares allocation; and

further comprising the step of calculating an assembly number of defects per opportunity from a standard normal deviate associated with an upper and lower specification limit includes calculating:

$$Z_U = \frac{\left[(USL - \mu_{Assy})^2 - \sum_{j=1}^{p} (a_j t_j)^2 \right]^{1/2}}{\sigma_{Assy,LT}}$$

$$Z_L = \frac{\left[(\mu_{Assy} - LSL)^2 - \sum_{j=1}^{p} (a_j t_j)^2 \right]^{1/2}}{\sigma_{Assy,LT}}$$

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Abstr. Idea

where

a_j=sensitivity of the j^{th} fixed component;

μ_{Assy}= mean value at the assembly requirement;

$\sigma_{Assy,LT}$=long-term standard deviation for the assembly requirement;

LSL=lower specification limit;

t_j= bilateral tolerance of the j^{th} fixed component;

p= number of fixed components;

USL=upper specification limit;

Z_U=the standard normal deviate associated with the upper specification limit; and

Z_L=the standard normal deviate associated with the lower specification limit.

34. The method of optimizing tolerances for a design of claim 1 wherein the step of determining an appropriate analysis/allocation method for determining tolerances of the plurality of components includes selecting a static root sum of the squares allocation; and

further comprises the step of calculating an assembly number of defects per opportunity from a standard normal deviate associated with an upper and lower specification limit includes calculating:

$$Z_{U,-} = \frac{\left[\left(USL - \mu_{Assy} + 1.5\sum_{k=1}^{q}\left|a_k\sigma_k\right|\right)^2 - \sum_{j=1}^{p}\left(a_j t_j\right)^2\right]^{1/2}}{\sigma_{Assy,ST}}$$

$$Z_{U,+}=\frac{\left[\left(USL-\mu_{Assy}-1.5\sum_{k=1}^{q}\left|a_k\sigma_k\right|\right)^2-\sum_{j=1}^{p}\left(a_jt_j\right)^2\right]^{1/2}}{\sigma_{Assy,ST}}$$

$$Z_{L,+}=\frac{\left[\left(\mu_{Assy}-LSL+1.5\sum_{k=1}^{q}\left|a_k\sigma_k\right|\right)^2-\sum_{j=1}^{p}\left(a_jt_j\right)^2\right]^{1/2}}{\sigma_{Assy,ST}}$$

$$Z_{L,-}=\frac{\left[\left(\mu_{Assy}-LSL-1.5\sum_{k=1}^{q}\left|a_k\sigma_k\right|\right)^2-\sum_{j=1}^{p}\left(a_jt_j\right)^2\right]^{1/2}}{\sigma_{Assy,ST}}$$

where

a_j=sensitivity of the j^{th} fixed component;

a_k=sensitivity of the k^{th} fixed component;

μ_{Assy}= mean value at the assembly requirement

$\sigma_{Assy,ST}$=short-term standard deviation for the assembly requirement;

$\sigma_{Assy,LT}$=long-term standard deviation for the assembly requirement;

p= number of fixed components;

t_j=Equal bilateral tolerance of the j_{th} fixed component;

LSL=lower specification limit;

USL=upper specification limit;

p=number of fixed components;

q= number of variable components;

Z_U=the standard normal deviate associated with the upper specification limit; and

Z_L=the standard normal deviate associated with the lower specification limit.

35. A method for applying variation controls for a feature of a component in an assembly of a plurality of components through a decision matrix for determining appropriate variation controls, said method comprising the steps of: non stat.

inputting a feature, controlled element of the feature, a tolerance zone shape and a relationship of tolerance zone to a datum reference frame into the decision matrix; and

determining, through the decision matrix, a variation control utilizing inputted information for automatically selecting and applying an appropriate variation control.

36. The method for applying variation controls for a feature of a component of claim 35 wherein the decision matrix is stored within a computer and the computer determines and applies the appropriate variation control by accessing the decision matrix.

37. The method for applying variation controls for a feature of claim 36 wherein a computer automatically determines a variation control utilizing the information provided by the user.

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38. A system for automatically applying variation controls of a feature of a component in an assembly of a plurality of components, said system comprising:

a computer system for calculating and determining variation controls of the feature;

a user interface for a user to input data relevant for determining variation controls of the feature; and

a memory for storing information applicable for applying variation controls;

whereby the user inputs all relevant data of the feature through the user interface to the computer system, said computer system calculating an appropriate variation control associated with the feature and applying the calculated variation control in an appropriate location determined by the computer system.